Index

A

Abegg, Richard, 78
Absolute temperature scale, 153–54
Absolute zero, 153–54
Acetate ions, 746–47
Acetic acid, 198, 436, 437
Acetylsalicylic acid (ASA), 339, 382
Acid–base equilibrium, 725
  collision–reaction theory and, 712
Acid–base indicators, 245–47, 336, 753–54. *See also names of individual indicators*
Acid–base reactions
  pH curves and, 761
  predicting of equilibria, 727–30
  and proton transfer, 724–26
  quantitative, 730
  titration of, 333
Acid–base theories, history of, 733–34
Acid–base titrations, 596
Acid deposition, 252, 393
Acidic solutions
  aqueous hydrogen ions and, 238
  hydrogen ions and, 237
  nature of, 236–35
  water ionization and, 713–14
Acid ionization constant, K_a, 737–43
Acid rain, 145, 190, 635, 721
Acids, 28
  in chemical reactions, 710
  conductivity of, 194, 200–201
  conjugate, 724–26
  defined, 249
  empirical definitions of, 28
  and hydronium ions, 249
  litmus test of, 194
  naming and writing formulas for, 34–36
  nomenclature, 248
  oxygen and, 733
  properties of, 198–99, 236–37
  reaction with water, 249
  strong. *See* Strong acids
  weak. *See* Weak acids
Actinoids, 16
Activated complex, 527–29
Activation energy, 526–30, 694
Addition polymerization, 445
Addition reactions, 419–21
Adhesion, 113
Aerospace engineers, 278
Air, 142, 148
Air bags, 146, 176, 351
Alberta Chemical Operations, 416
Alcohols, 399, 425, 427, 428, 430
Aliphatic hydrocarbons, 379
Alizarin yellow indicator, 336, 753
Alkali metals, 16
Alkaline-earth metals, 16
Alkanes, 362, 366–73, 367–69, 382, 540
Alkenes, 374–77, 375–78, 376
Alkylation, 390
Alkylbenzene, 382
Alkyl branches, 367
Alkyl halides, 417
Alkynes, 374–77, 375–78, 376
Alloys, 27, 83, 192
Aluminium, 290, 558, 634, 647–48, 652
Aluminium oxide, 432
Amides, 452
Amines, 363, 452
Amino acids, 112, 115, 452–53
  chirality of, 114–15
Ammeter, 613
Ammonia
  geometry of, 93
  Haber process for production of, 325–26
  uses of, 332
Amount concentration, 205–206, 694
  calculating K_b from, 745–46
Amount of substance, 51
Amperes, 613
Amphiprotic, defined, 723
Amphoteric, defined, 723
Amphoteric substances, 749–50
Analogies, 18
Analytic measurement technology, 337–38
Anions, 24, 120, 248, 624
Anodes, 613, 616, 624, 626, 628–29, 636
Anomalies, 677
Antifreezes, 425, 426
Antioxidants, 430
Aqueous acid solutions
  percent reactions, 718
  strengths of, 829
Aqueous bases, strengths of, 829
Aqueous hydrogen ions, 238
Aqueous hydroxide ions, 35, 238
Aqueous solutions, 29
  conductivity of, 193–94, 197
  properties of, 193–94
  proton transfer in, 729–30
Aristotle, 149
Aromatics, 381–85
Arrhenius, Svante, 19, 197, 198, 237, 248, 525, 526, 574, 575, 734
Arrhenius theory, 713, 722, 734
  modified, 248–51, 255, 256, 713, 718, 737
Ascorbic acid, 438
Astronomy, 315
Athabasca oil/tar sands, 361, 395–96
Atmospheric pressure, 149
Atomic molar masses, 490
Atomic numbers, 21
Atomic theory, 6, 18–19, 583
Atoms, 12, 18–19
  counting of individual, 337–38
Aureate plating, 556, 651
Avogadro, Amedeo, 165
Avogadro's number, 51, 85
Avogadro's theory, 165, 169

B

Bacon, Francis, 617
Balanced chemical equations, 48–50, 52–54
  energy terms in, 498
  and enthalpy changes for reactions, 497
  mole ratio from, 321–22
  and reaction stoichiometry, 287
  translating, 51–52
Balmer, Johann, 23
Base ionization constant, K_b, 744–50
Bases, 28, 35–36
  conjugate, 724–26, 728
  definition of, 250
  dissociation of, 198, 248
  empirical definitions of, 28
  litmus test on, 194
  properties of, 198–99, 236–37
  reaction with water, 249, 250
  strength of, 744
  strong. *See* Strong bases
  weak. *See* Weak bases
Basicity, prediction of, 746–49, 748–49
Basic solutions
  aqueous hydroxide ions and, 238
  hydroxide ions and, 237
  nature of, 236–37
  water ionization and, 713–14
Batteries
  See also Electric cells
  car, 616, 617
  dead, 632
  defined, 612
  for electric vehicles, 610
  energy density of, 614
  lead–acid, 610, 616, 617
  9 V, 615
  plastic, 621
  power of, 614
Bauxite, 290, 648
Becquerel, Henri, 46
Benzene, 381, 382, 430
Beryllium, 94
  dihydride, 92
Binary compounds, 29
  ionic, 120, 121
  molecular, 33
Bio-based economies, 507–508
Biochemists, 91
Biodegradability, 456
Biopolymers, 458
Birss, Viola, 552
Bitumen, 394, 395–96, 539–40
Bleaching, of wood pulp, 594
Bleach (sodium hypochlorite), 212–13
Blood
  alcohol content, 312, 588
  equilibrium of circulation, 692
Blood plasma, 190
  ions in, 200
Bohr's atomic theory, 21–23
Boiling points, 106, 107–108, 109, 121, 155
Bondar, Roberta Lynn, 278
Bond breaking, 532–33
Bond dipoles, 101
Bond energies, 99, 105, 532, 533
Bonding/bonds, 82–84
  carbon, 126–27
  tetrahedral, 92, 93, 94
  theories, 72, 76
  triple, 85
Bonding capacity, 87
Bonding electrons, 80

Bond polarity
electronegativity and, 99–101
molecular polarity and, 101–103
Boron, 94
Bosch, Carl, 325
Boyle, Robert, 150, 151, 163
Boyle's law, 151, 156, 160, 163, 169, 694
Breathalyzers, 312, 580
Bromothymol blue indicator, 245, 246, 336, 752, 753, 760
Brønsted, Johannes, 722, 734
Brønsted–Lowry acid, 723
Brønsted–Lowry base, 723
Brønsted–Lowry concept, 722–36, 723, 727, 728, 744, 755
Brønsted–Lowry equations, 756, 764
Brønsted–Lowry reaction equations, 723, 758
Bronze, 560
Brooks, Harriet, 25
Buffer capacity, 764
Buffering, 751, 752, 763–65
Buffers, 766
Bunsen, Robert Wilhelm, 23, 315
Burettes, 328
Buriak, Jillian, 123
Burning
corrosion and, 559
of fossil fuels, 190, 357
oxygen and, 559

C

Calcium hydroxide. *See* Slaked lime
Calorimeters, 485, 486, 487, 498, 502, 507, 515
Calorimetry, 485–87, 495, 498, 502, 533
Capillary action, 105, 113, 114
Carbohydrates, 449
Carbon
covalent networks of, 126–27
oxidation number of, 585–88
Carbon cycle, 356–57
Carbon dioxide, 356, 585
in combustion, 399
crystal structure of, 124
oil recovery and, 388
Carbon monoxide, 320, 399, 502, 503
Carboxyl group, 436
Carboxylic acids, 436–37
Carcinogens, 381, 417
Careers, 10. *See also names of particular careers*
Carothers, Wallace, 453
Catalysis, 535
empirical effect of, 535–36
theoretical explanation of, 536–39
Catalysts, 522, 523, 535, 539–41, 694
Catalytic converters, 522, 523, 535
Catalytic cracking, 389
Catalytic reforming, 390
Cathodes, 613, 616, 624, 626, 628–29
Cathodic protection, 636
Cations, 24, 120, 248, 624
Cavendish, Henry, 152
Cell notation, 622
Cellular respiration, 500, 556, 565
Cellulose, 455
acetates, 458
starches vs., 456–57
Celsius temperature scale, 153, 295
CFCs. *See* Chlorofluorocarbons (CFCs)
Charles, Jacques, 152, 153, 155, 163, 164
Charles' law, 154–55, 156, 163–64, 169
Chemical amount, 51, 55–57
Chemical analysis, 314–16
Chemical changes, 9, 46. *See also* Chemical reactions
energy transformations and, 474
at molecular level, 670
Chemical decomposition, 12
Chemical energy
personal use of, 482
transportation and, 482
Chemical engineering technologists, 480
Chemical engineers, 284, 412
Chemical formulas, 13
states of matter in, 29
subscripts, 49
Chemical industry employees, 415
Chemical potential energy diagrams, 498–99, 529
Chemical process engineers, 693
Chemical reaction equilibrium, 670, 677, 678–83
Chemical reactions, 9, 42, 47–50, 76. *See also* Chemical changes; Hydrogen–iodine reaction system
acids in, 710
assumptions regarding, 280–81
calculating masses in, 288
classification of, 58–60
communicating, 48–49
equations. *See* Reaction equations
forward. *See* Forward reactions
generalizations about, 58
homogeneous vs. heterogeneous, 682
quantitativeness of, 281, 677, 680
rate of, 524
reverse. *See* Reverse reactions
in solution, 61–63
speed of, 280–81
spontaneity of, 280, 676
as stoichiometric, 281
stoichiometry of, 287
Chemicals, common, 830
Chemical systems, 676. *See also* Closed systems
Chemical technologies, 270, 274, 286. *See also* Technology/technologies
evaluation of, 524
Chemical technologists, 286, 650
Chemistry, 6, 9
defined, 9
and technology, 270, 274
Chemistry teachers, 9
Chlor-alkali process, 648
Chloride anomaly, 645, 648
Chlorine
gas, 645, 646
uses of, 648
Chlorobenzene, 421–22
Chloroethene, 420, 447
Chloroethene (vinyl chloride), 421
Chlorofluorocarbons (CFCs), 184, 417, 418, 419, 422, 530
Chlorophyll, 535
Cholesterol, 375
CHP. *See* Cogeneration
Chromium, 128, 327, 350, 650
Chuang, Karl, 390
Citric acid, 255, 437
Clark, Karl, 394, 395
Claus converters, 363
Cleaning solutions/products, 119–20, 220, 238, 268
Closed systems, 676–78, 689
Coal, 358, 361, 505, 585
Coalbed methane, 358, 365
Coefficients, 49
Cogeneration, 505, 618
Cohesion, 113
Coking, 396, 540
Collision–reaction theory, 47, 120, 249, 281, 524–26, 563, 676, 728
acid–base equilibrium theory and, 712
concentration changes and, 692
and energy changes, 693
and gas volume changes, 694
and reverse reactions, 677
Colorimetry, 314–16
Combined gas law, 156–57, 169
Combustion, 522, 556
in automobiles, 146, 399
complete, 398–400
complete reactions, 58–59
corrosion and, 559
incomplete, 398–400
Communication, 10, 87, 811–16
Compounds, 12–13, 13, 76
binary, 29
classification of, 27–31
empirical definitions of, 28
molecular, 33–34
thermodynamic properties, 826
Computer chip industry, 159, 338
Concentration changes
collision–reaction theory and, 692
and Le Châtelier's principle, 691–92
Concentration(s). *See also* Amount concentration
acid ionization constant, K_a and, 738
calculating, 206–210, 216–17
dilution of solutions and, 216–18
equilibrium and, 719
and equilibrium constant, 685
hydronium ion, 238–39
of ions, 210–13
maximum solute, 221
parts per billion (ppb), 204–205, 214
parts per million (ppm), 204–205, 207
percentage, 203–204
pH, 716–18
pOH, 716–18
predicting of, at equilibrium, 686–87
solutions, 203
strength vs., 737

Condensation polymerization, 449
Condensation reactions, 438
Conductivity, 28
and acid strength, 718–20
of aqueous solutions, 193–94, 197
Arrhenius' theory and, 713
of pure water, 713
Conjugate acid–base pairs, 725
K_a–K_b relationship for, 746–49
Conservators, 580
Constant relationships, 685
Consumer products
information on, 809
Cooley, Jean, 352
Coordinate covalent bonds, 87
Copper
bonding in, 124
early uses of, 560
electrorefining of, 649
in silver–copper cells, 623–24
Correlational studies, 450
Corrosion, 120, 559, 634–35, 636–37
Corrosiveness, 810
Cotton, 457
Coulombs, 613
Covalent bonds, 78, 82, 86, 111
double, 86–87, 96
triple, 87, 96
Covalent networks, 125
Cracking, 378, 389–90
ethane, 414, 431–32
Crude oil
cracking and reforming of, 539
discovery of, 360
refining of, 358, 386–87
Cryolite, 647
Crystal lattice, 122
Crystal lattices, 83, 121, 122
Crystallization, 76, 77, 802
Crystallography, 82, 91, 96
Crystals
covalent network, 125–27
diamond, 125
ionic, 119–23
metallic, 123–24
molecular, 124
quartz, 126
three-dimensional models of, 121
X-ray diffraction of, 121
Cycloalkanes, 371–73, 374, 375, 430
Cycloalkenes, 376–77, 430
Cycloalkynes, 376–77
Cyclohexanol, 430

D

Dacron, 451
Dalton, John, 13, 18–19, 46
Dalton's atomic theory, 18–19, 163
Davy, Sir Humphry, 197, 237, 646, 653, 733–34
DDT (dichlorodiphenyltrichloroethane), 277, 417
Deductive reasoning, 538–39
Dehydration, 432
Dehydrogenation, 379
Dehydrohalogenation, 432
Describing, 72, 78, 276
Detergents, 103, 210, 541
Dewaxing, 387
Diabetes, 681
Diagnostic tests, 28, 48, 805
for ions, 284
Diamond(s), 125, 128
Diatomic molecules, 33, 85
Dicarboxylic acids, 436, 451
Dichromate ions, 596
Diethylbenzene, 382
Dihydrogen phosphate ions, 764
Dilutes, 203
Dilution, 216–18
Dimethylpropane, 368
Dioxins, 594
Diploma Exam, 823–25
Dipole–dipole forces, 106, 107
Diprotic bases, 335, 756
Disaccharides, 456
Disproportionation reactions, 577, 592
Dissociation, 197, 198, 210–211, 249, 250
DNA molecule, 113
Döbereiner, Johann, 538
Doping, 127
Double helix, 112
Double replacement reactions, 62–63, 251
Dry cleaning, 103
Ductile, defined, 15
Dynamic equilibrium, 224–26, 670, 674, 677

E

Ecological perspectives, 45
Ecologists, 240
Economic perspectives, 45
Edison, Thomas, 619
Einstein, Albert, 18, 21, 78
Electric cars. *See* Electric vehicles
Electric cells. *See also* Batteries
alkaline, 615, 617
dead, 632
defined, 612
design and properties, 613–14
dry, 615
galvanic, 622
lithium-ion, 616
membrane, 648
mercury, 615
nickel–cadmium, 616, 640
power of, 614
as power source for electrolytic cells, 646
primary, 615
rechargeable, 615, 640
secondary, 616–17, 640
silver–copper, 623–24
stoichiometry of, 652–57
voltaic cells vs., 626
zinc chloride, 615
zinc sulfate, 639
Electric current, 612–13, 613
direction of, 628
impressed, 636
Electricity
current, 558
as flow of electrons, 613
fuel cells and, 617
and redox reactions, 610
static, 612
Electric potential difference, 613
Electric vehicles, 481, 610, 618
Electrochemical cells, 626, 640, 655
Electrochemical reactions, 552
Electrochemistry, 556
Electrodes, 613
Electrolysis, 297, 298, 610, 640, 646–51
Electrolytes, 193–94, 197, 613
acids as, 198
conductivity of, 197
and rusting, 635
Electrolytic cells, 639–51
electric cells as power source for, 646
potassium iodide, 641–42
Electronegativities, 83, 86, 99–101
Electronegativity, 81
Electrons
"bookkeeping," 583
loss and gain of, 583, 652
Electron transfer(s), 78, 83, 85, 552, 583, 585, 589
in biological systems, 632
in electrolytic cells, 641
theory, 561–62
Electroplating, 327, 650, 669
Electrorefining, 649
Electrowinning, 650
Elements, 12, 13
classification of, 14–17
empirical knowledge of, 18
families of, 14
IUPAC rules, 15–16
molecular, 33, 85–86
production of, 646–48
rare earth, 16
solubility of, 222
thermodynamic properties, 826
Elimination reactions, 432
Emissions
control, 540
Empirical definitions, 10
of acids, 28
of bases, 28
of compounds, 28
of neutral compounds, 28
Empirical formulas, 30, 88
Empirical hypotheses, 10
Empirical knowledge, 10. *See also* Evidence; Scientific knowledge
observations and, 18
theories vs., 524–26
Endothermic changes, 200, 486, 498–99
Endothermic reactions, 111, 489, 498, 532
Endpoint, 751
Endpoints, 328, 596, 751, 758
Energy
alternative sources and technologies, 507–508
changes, 199–98, 485–86, 488

consumption, 480, 481
density, of batteries, 614
industry/sector, 480, 508
kinds of, 474
pathway, 527–29
production, 481
quantum theory of, 21
renewable sources, 496, 507–508
saving for future use, 482
and technologies, 474
transfers, 532
transformations, 474, 499
Engine knock, 392, 393
Enthalpies of reaction, 490, 510
Enthalpy changes, 487–89, 488, 490, 496–97, 502, 527, 533
Entities, 12
Environment
Aboriginal peoples and, 186, 252, 481
damage to, 6, 45
disposable diapers and, 455–56
electric vehicles and, 610
fossil fuels and, 360
technology and, 277
Environmental engineers, 714
Enzymes, 91, 535, 541
Equilibrium, 670, 674, 677
acid strength and, 718–20
adjusting by adding/removing a substance, 691
in biological systems, 692
blood sugar, 681
catalysts and, 694
closed systems at, 676–78
concentration and, 719
and modified Arrhenius theory, 718
position of, 680
prediction of concentrations at, 686–87
solutions in, 224
temperature and, 719
and volume vs. pressure, 694
Equilibrium constant, K_c, 684–87, 713
Equilibrium law, 684
Equilibrium shifts, 691
Equivalence points, 328, 333, 334–35, 751, 755, 756, 761
Erlenmeyer flask, 215
Ester functional group, 439
Esterification reactions, 438
Esters, 439–44
as artificial flavourings, 439
naming of, 439–40
natural, 441
wax, 441
Ethane, 378–79, 379, 414, 431–32
Ethanoic acid. *See* Acetic acid
Ethanol, 312, 399, 425–26
Ethene (ethylene), 374, 378, 414–15, 431–32
Ethylene dichloride, 420, 423
Ethyne, 97–98
Ethyne (acteylene), 375
Evaluations, of investigations, 791–92, 796
Evaporation, 113
Evidence, 9, 25, 163, 248, 710, 791, 795. *See also* Empirical knowledge
tables of, 10
Excess reagents, 284, 318
calculating mass of, 320
identifying limiting, 321–22
Exothermic changes, 200, 486, 498–99
Exothermic reactions, 111, 489, 496, 498, 527, 532–33
Experimental error, 792
Experimental uncertainties, 292
Experiments, 8, 18
controlled, 148
prediction of results, 249
Explaining, 72, 78, 276

F

Families, of elements, 14, 16
Faraday, Michael, 19, 197, 381, 625, 653
Faraday constant, 653, 655
Faraday's law, 653
Fatty acids, 449
Feedstocks, 389, 410, 508
Fermentation, 312
Fertilizers, 325–26, 349, 696
Field production operators, 540
Filtration, 291, 802–803
Fire(s), 522
as early technology, 567
extinguishers, 559
metal refining and, 559
Flammability, 113, 810
Foods
digestion of, 710
energy content of, 486, 520
labelling of product ingredients, 331, 349
preparation, 274
Food science technologists, 681
Force, 149
Forensic laboratory analysts, 48
Formation reactions, 58, 510
Formic acid. *See* methanoic acid
Formulas
molecular, 85–90
simplest ratio, 86
stereochemical, 88
types of, 87–88
Formula units, 30
Forward reactions, 677, 680
concentration changes and, 691–92
proton transfer and, 724–25, 726
temperature and, 693
volume and, 694
Fossil fuels
alternatives to, 481, 507–508
burning of, 190, 357, 482
chemical energy and, 480
classifying, 359
environment and, 360
fuel cells vs., 617
industries, 359–60
origin of, 356, 480
refining of, 358
Fractional distillation, 386, 388
Fractionation, 386–87
Fractions, 386–87, 497
Fractures, 119
Frankland, Edward, 78
Franklin, Ursula, 321
Freezing, 113, 155
Freons. *See* Chlorofluorocarbons (CFCs)
Fuel cells, 481, 508, 556, 617–20
aluminium–air, 610, 618
aluminium–oxygen, 618
Ballard, 620
hydrogen, 293, 296, 620
hydrogen–oxygen, 617
large-scale uses, 618
phosphoric acid, 618
research into, 552
Fuels
alternative, 478
hydrogen as, 481
renewable, 482
Functional analogs, 449
Functional groups, 417

G

Galileo, 149
Galvani, Luigi, 612, 622
Galvanizing, 636, 637
Gases, 142
air and, 142
chemical safety hazards of, 159–60
compressed, 159–60, 163, 170
density of, 176
empirical properties of, 148–62
ideal. *See* Ideal gases
liquefied, 170, 414
molar volume of, 169–71
motion of molecules in, 163
noble. *See* Noble gases
pressures of, 149, 159–60, 163
properties of, 163–68
quantity calculations, 295
real vs. ideal, 172
solubility of, 222
technologies, 146
uses of, 148
Gasohol, 311, 482
Gasoline, 113, 192
ethanol in, 399, 426
octane and, 392
production, 539
sulfur in, 393–94
Gas stoichiometry, 288, 294–97
Gay-Lussac, Joseph, 164–65
Gemmologists, 125
Generalizations, 11, 154, 222–23, 645
Geologists, 125
Giguère, Paul, 237
Gillespie, Ronald, 91, 93, 724
Glass, 119, 126
Global warming, 492, 540
Glucose–glucose linkages, 456–57
Glycerol, 429, 430, 449
Glycogen, 457
Gold, 15, 20, 560
Grain alcohol. *See* Ethanol

Graphite, 126–27
Graphs, 10, 317, 815–16
Gravimetric analysis, 314, 317–19
Gravimetric stoichiometry, 288
Gravitational potential energy, 482, 526–27
Grease, dissolving of, 103, 196
Greenhouse gases (GHGs), 400, 540
Groups of elements, 14, 16
Grove, William, 617
Guillet, James, 449
Guldberg, Cato Maximilian, 684

H

Haber, Fritz, 325, 617, 690
Haber process, 325–26, 693
Half-cells, 622
    overvoltage, 645
    reference, 627
    standard hydrogen, 627
    standard reduction potential of, 628–30
    stoichiometry calculations, 655–56
Half-reaction equations, 562, 564–67, 570, 589
Half-reactions, 561
    and predicting redox reactions, 579
Halides, 417, 423, 424, 433, 571
Hall, Charles, 647
Halogens, 16, 417
Harrison, Jed, 338
Hazards
    of gases, 159–60
    of household chemical solutions, 212–13
Heat
    energy as, 485
    transfer, 487–89
Heat capacities, 826
Heavy metal compounds, 810
Helium, 160, 170, 364
Hell–Volhard–Zelinsky reaction, 779
Hemoglobin, 130, 692
Heptane, 390
Héroult, Paul, 647
Herzburg, Gerhard, 109
Hess, Germain H., 502
Hess' law, 502–507, 510–13, 533
Heterogeneous mixtures, 12
Homeostasis, 765
Homogeneous mixtures, 12, 61, 192
Homologous series, 366
Hot-air balloons, 152, 156, 176
Household chemical solutions, 212–13
Huggins, Maurice, 111
Hybrid cars, 478
Hydrocarbon derivatives, 417
    hydrocarbons vs., 417
Hydrocarbons, 358
    aromatic, 540
    cyclic, 371
    hydrocarbon derivatives vs., 417
    saturated, 374
    solutions, 192
    unsaturated, 374
Hydrochloric acid, 200–201, 234, 255, 421–22, 778
Hydrochlorofluorocarbons (HCFCs), 184, 419
Hydrocracking, 390, 396, 540
Hydrogen
    and acidic properties, 237
    fuel cells, 293, 296
    production by steam reforming, 297
Hydrogenation, 374, 393, 419, 450
Hydrogen bonding, 111–13
Hydrogen chloride, 421–22
Hydrogen fuel cells, 297–98
Hydrogen gas, 747
    as fuel, 481
    in fuel cells, 507–508
    uses of, 648
Hydrogen–iodine reaction system, 679–82
Hydrogen ions, 237
Hydrogen phosphate ions, 764
Hydrogen sulfide gas, 362, 363
Hydrologists, 330
Hydrometallurgy, 644
Hydronium ions, 237, 238–39, 248, 255, 712, 713, 718–20, 729, 730, 744
    acids and, 249
    emphasis on, 747
    pH and, 240, 241
Hydrotreating, 393, 396, 540
Hydroxide ions, 198, 237, 238, 713, 729, 730, 744, 747
    pOH and, 243–44
Hydroxyl groups, 425, 428
Hypotheses, 8, 9, 98, 154, 790

I

ICE table, 681
Ideal concepts, 172
Ideal gases, 172
Ideal gas law, 172–76, 296
Immiscibility, 222
Indigenous knowledge (IK), 162, 163, 222. *See also* Traditional ecological knowledge
Inductive reasoning, 538–39
Inert electrodes, 625
Inflection point, 335
Inhibitors, 536
Intermediates, 538
Intermolecular bonding, 201
Intermolecular bonds, 111
Intermolecular forces, 105–18
    and liquids, 113
    research in, 114–15
International System of Units. *See* SI (Système International d'Unités)
International Union of Pure and Applied Chemistry (IUPAC), 14, 15–16, 29
Interpretations, 9–10
Intramolecular bonds, 111. *See also* Covalent bonds
Intramolecular forces, 105
Investigations, 8
    reports, 790–92, 796
Iodine. *See also* Hydrogen–iodine reaction system
    model of crystal of, 124
Ionic bonds, 78, 83
Ionic compounds, 27–28, 29–31, 58, 86
    binary, 120, 121
    empirical formulas, 88
    formation of, 120
    soluble, 119
Ionic crystals, 119–23
Ionic hydrates, 31
Ionic hydroxides, 194
Ionization, 198
Ionization constant for water, K_w, 713–16
Ions, 23–24
    concentration of, 210–11
    diagnostic tests for, 284
    electric particles as, 197
    origin of term, 625
Iron, 120, 634–35, 636
Isoelectronic molecules, 108
Isolated systems, 485
Isomers, 370
    cis, 423
    trans, 423
Isotopes, 21, 24
    radioactive. *See* Radioisotopes

J

Jackson, Chevalier, 715
Jalilehvand, Farideh, 728
Joule, James Prescott, 487
Joules, 485

K

Kebarle, Paul, 683
Kekulé, August, 381
Kekulé, Friedrich, 78, 82
Kelvin, Lord, 153, 154
Kelvin temperature scale, 153, 295
Kevlar, 454
Kilby, Jack, 652
Kilojoules, 486
Kilopascals, 149
Kinetic energy, 482, 487–88, 510, 527, 632
Kinetic molecular theory (KMT), 47, 163–64, 172, 224
Kirchhoff, Gustav Robert, 23, 315

L

Laboratory equipment, 797–801
Laboratory reports, 8
Laboratory safety, 807–808
Lactic acid, 255
Language, scientific, 49, 811
Lanthanoids, 16
Lauks, Imants, 598
Lavoisier, Antoine Laurent, 680, 733
Law of additivity of enthalpies of reaction. *See* Hess' law
Law of combining volumes, 164–66
Law of conservation of energy, 488, 491, 498, 499, 502
Law of conservation of mass, 11, 18, 19, 48

Law of definite composition, 18, 19
Law of mass action, 684
Law of multiple proportions, 18, 19
Laws, 9
Le Bel, Joseph, 78
Le Châtelier, Henri Louis, 690
Le Châtelier's principle, 690, 691–92, 693, 694
LEDs (light-emitting diodes), 126
Lemieux, Raymond, 460
Le Roy, Robert J., 114
Le Roy radius, 114
Lewis, Gilbert, 78, 81, 91, 734
Lewis formulas, 81–82, 85, 88, 89, 91, 92–96
Lewis symbols, 81
Liebig, Justus von, 237, 538, 734
Lime, 120, 511. *See also* Quicklime; Slaked lime
Limestone, 511
Limiting reagents, 284
Lind, James, 744
Lipids, 449–51
Liquefied petroleum gases (LPGs), 414
Liquids
  motion of molecules in, 163
  physical properties of, 113–14
  solubility of, 222
Litmus indicator, 194, 198, 236, 245, 246, 333, 641
Logarithmic scales, 240, 243, 716–18
London, Fritz, 106, 107
London forces, 106–10
Lone pairs, 80
Loschmidt, Josef, 381
Lowry, Thomas, 722, 734
LPGs (liquid petroleum gases), 378
Lye. *See* Sodium hydroxide

M

MacGill, Elizabeth ("Elsie"), 164
Main group elements, 16
Malleability, 15, 20
Mallory, Walter, 619
Manuel, Rob, 387
Marcus, Rudolph, 561
Margarine, 374
Marker, Russell, 392
Mass
  calculation of, 209
  numbers, 21
Materials engineering technologists, 636
Materials/metallurgical engineers, 558
Materials Safety Data Sheets (MSDS), 385, 809
Matter
  changes in, 46–50
  classification of, 12–13
  defined, 12
Medical laboratory technologists, 246
Melting points, 110, 121, 126
Mendeleev, Dmitri, 14, 23
Menten, Maud, 766
Mercaptans, 362
Metabolism, 556, 565
Metal ions
  flame tests for, 315
Metallic bonding, 83, 124
Metallurgy, 558, 567
  early, 560
Metals, 14–15
  crystals of, 123–24
  electronegativities of, 81
  extraction of, 120, 558
  multi-valent, 29–30
  refining of, 559, 649–50
  toxicity of, 337
Meteorologists, 166, 167
Methane, 378
  coalbed, 358
  geometry of, 93
  mining of, 364
Methanoic acid, 436, 537, 539
Methanol, 425–26
Methylbenzene, 382, 390
Methylbutane, 367
Methyl orange indicator, 758, 760
Methyl red indicator, 753, 754
Microbiologists, 766
Microchips, 652
Micromachining techniques, 338
Microscopes, 25, 115
Miscibility, 222
Mixtures, 12, 192
Models, 18
  molecular, 49, 90, 377, 378
Mohs Hardness Scale, 128
Molar enthalpies of combustion, 495
Molar enthalpies of formation, 495, 510–15, 533
Molar enthalpies of reaction, 490, 495–96, 510
Molar mass, 55–57
Molar quantities, 490
Molar volume, 169–71, 490
Molecular compounds, 27–28, 33–34, 58, 86–87
  formulas, 88
  solubility of, 201
Molecular crystals, 124
Molecular elements, 85–86
Molecular formulas, 33, 85–90
Molecular polarity
  bond polarity and, 101–103
  dipole theory, 98–103
Molecular shapes, 91, 92–98
Molecules, 13, 33
Moles, 51, 52, 169, 209
Molicel, 616, 669
Momentary dipole, 106
Monatomic ions, 23–24
Monobasic bases, 258
Monomers, 445
Monoprotic acids, 258
Monoprotic bases, 258
Monosaccharides, 456
Multiple choice questions, 823–24
Muriatic acid. *See* Hydrochloric acid

N

Naphthas, 387
Natural gas
  consumption, 398, 413
  discovery of, 359–60
  emissions, 385
  extraction of, 362
  helium from, 364
  pipelines. *See* Pipelines
  processing plants, 364
  refining of, 358, 363–64
  sour, 363
  sweet, 363
Natural gas liquids (NGLs), 414
Natural resources, 356, 360, 410
  nonrenewable, 357
  renewable, 354
Nernst, Walther, 617
Net ionic equations, 281–84, 334, 562, 563
Neutral compounds, 28
  empirical definitions of, 28
  litmus test on, 194
Neutralization, 63, 251, 734, 751
Neutrons, 21
Newtons, 149
Nitric acid, 200–201, 255
Nitrogen
  cycle, 609
  liquefied, 170
Noble gases, 16, 120, 159, 174
Noddack, Ida, 15
Nomenclature, 29, 680, 746
Nonelectrolytes, 193–94, 197
Nonmetals, 15
  electronegativities of, 81
  oxides, 251, 252
  reactions of, 571
Nonpolar covalent bonds, 99
Nonpolar molecular compounds, solubility of, 201
Nonpolar molecules, 98, 101, 106
Nuclear changes, 46
Numerical response questions, 824
Nyholm, Ronald, 91, 93
Nylon, 449, 453–54

O

Observations, 9, 18, 163
  predictions about, 249
  redox theory and, 563
Octadecanoic acid. *See* Stearic acid
Octane numbers, 392–93, 425
Octet rule, 80, 85
Ohmmeter, 194
Oil industry
  catalysts in, 539–40
  pipelines. *See* Pipelines
Oil refining, 360, 522
  chemical processes in, 389–90
  physical processes in, 386–88
Oil sands, 358, 359, 392, 394
Orange IV indicator, 753
Orbitals, 80, 85

Organic chemistry, definition of, 358
Organic compounds
  as hydrocarbons vs. hydrocarbon derivatives, 417
  molecular formulas for, 370
Organic halides, 417
Oxalic acid, 255, 437
Oxidation, 281, 559, 562, 563, 583, 585
Oxidation numbers, 583–85, 589–93
Oxidation states, 583–84
Oxidizing agents (OAs), 559, 568–69, 569, 828
Oxyacetylene torches, 375
Oxygen, 142
  acids and, 733
  atomic, 530
  liquefied, 170
  molecular, 530
  naming of, 733
  role in burning, 559
Oxygenation, 399
Oxygenators, 425
Ozone, 418, 530

P

Particles, 12, 120
Pascals, 149
Pasteur, Louis, 82
Pauli, Wolfgang, 80
Pauli exclusion principle, 80
Pauling, Linus, 78, 81, 82, 91, 99–100, 107
PCBs (polychlorinated biphenyls), 417
Pentane, 367, 368
Peptides, 452
Percent difference, 792
Percent ionization, 718
Percent reaction, 718, 720
Percent yield, 292, 680, 792
Periodic law, 21
Periodic tables, 6, 14, 15, 21, 30
Periods, 14
Permafrost, 118
Perspectives, 45
Pesticides, 224
Petrochemicals, 356, 357, 410, 413–16, 423, 522
Petroleum, 381
Petroleum engineers, 387
Petroleum Human Resources Council of Canada, 389
pH, 236, 239
  of acid vs. normal rain, 721
  buffers and, 764–65
  calculations, 240–42
  changes during titration, 333
  dependence on, 241
  emphasis on, vs. pOH, 747
  hydronium ions and, 240, 241
  measurement of, 241, 242
  precision rule for, 814
  scale, 236, 237, 239
  of soils, 251
  test strips, 246
Phase equilibrium, 677
pH concentrations
  logarithmic scale, 716–18
pH curves, 751–67
  acid and base strength vs., 760–63
  for strong acid–strong base reaction, 751
  titration, 334–35
Phenolphthalein indicator, 245, 753, 760
Phenols, 430
Phenyl group, 382
pH meters, 333
Phosphoric acid, 432
Photodegradability, 449
Photosynthesis, 142, 480, 535, 556, 567, 588
Physical changes, 9, 46
Pidgeon, Lloyd, 649
Pidgeon process, 649
Pipelines, 360, 364
Pipettes, 218, 800–801
pK_a, 742
Planck, Max, 21
Plastics, 445, 449
pOH
  emphasis on pH vs., 747
  hydroxide ions and, 243–44
  precision rule for, 814
pOH concentrations
  logarithmic scale, 716–18
Polanyi, John, 87, 534
Polar compounds, solubility of, 201
Polar covalent bonds, 99–100
Polar molecules, 98, 103
Political perspectives, 45
Pollutants, 146, 207, 224, 251, 252, 332, 393, 400
Pollution, 160
  dilution and, 219
  electric vehicles and, 610
  technology and, 356
Polyalcohols, 429
Polyamides, 453
Polyatomic ions, 30, 121
Polyatomic molecules, 85
Polybasic bases, 258
Polycarboxylic acids, 437
Polyesters, 451
Polymerization, 116, 445, 448, 452, 456
Polymers, 286, 414, 445–48, 449
Polypeptides, 453
Polyphenols, 430
Polypropylene, 445, 446, 455
Polyprotic acids, 258, 755
Polyprotic bases, 258, 755
Polyprotic entities, 756, 757, 758
Polysaccharides, 456
Polystyrene (Styrofoam), 445, 447
Polyvinylchloride (PVC), 414, 420, 445, 447
Popper, Karl, 25
Porous boundaries, 622
Potassium hydrogen phthalate, 330
Potassium hydroxide, 432, 617, 669
Potential energy, 487–90, 510, 632
Precipitates, 61, 225, 291
Precipitation, 63, 252
  completeness of, 318–19
Predicting, 72, 78, 276
  acid–base reaction equilibrium, 727–30
  acid–base reactions, 728–30
Prediction(s), 8, 25, 96, 97, 163, 790–91
  about observations, 249
  of basicity, 746–49, 748–49
  of concentrations at equilibrium, 686–87
  of empirical formulas, 29
  quantitative, 286–85
  of results in new situations, 251
  of results of experiments, 249
  testing of concepts and, 290
  testing of stoichiometric, 291
Pressure, 148–50
  amount concentration and, 694
  of gases, 159–60, 163
  reaction equations and, 279
  volume and, 150–52, 694
Priestley, Joseph, 733
Primary standards, 330, 596
Problem solving, 8
  methods, 816
  scientific. *See* Scientific problem solving
  STS. *See* STS (science, technology, and society)
  technological. *See* Technological problem solving
Propane, 378, 482
Propene (propylene), 374, 379
Proteins, 112, 115, 449, 452
  formation from amino acids, 452–53
Proton exchange membrane (PEM), 620
Protons
  hydrated, 237
  loss or gain of, 755
Proton transfer, 722–26, 728–30, 737, 755
Pure substances, 12

Q

Qualitative analysis, 314
Qualitative observations, 9
Quantitative analysis, 314, 317
Quantitative observations, 9
Quantities
  descriptions and rules for, 813–15
  reaction equations and, 279
Quantum mechanics, 79, 86
Quarks, 23
Quartz, 125, 126
Quicklime, 736

R

Radioisotopes, 24
R&D (research and development). *See* scientific research and development (R&D)
Reaction coordinates, 498
Reaction dynamics, 534
Reaction equations, 278–79, 279
Reaction kinetics, 525
Reaction mechanisms, 538
Reaction progress, 498, 524
Reaction quotient, 687

Redox equations, balancing of, 589–93
Redox reactions, 562, 568
in biological systems, 587
electricity and, 610
evaluation of predicted, 645
in living organisms, 588
oxidation numbers and, 585–86, 589–93
predicting, 575–81, 579
stoichiometry, 596–600, 676
as theory, 563
theory of, 583
Redox spontaneity rule, 569, 572, 628, 676
Redox tables, 569–70, 572–74, 575, 624
Redox titrations, 596
Reducing agents (RAs), 558, 568–69, 569, 828
Reduction, 558, 562, 583, 585
half-reactions, 562
theoretical vs. empirical definitions of, 563
Reduction–oxidation reaction. *See* Redox reactions
Reference energy state, 510
Reference half-cells, 627
Refining, 358
Replacement, of theories, 25, 72
Replication, 792
Restriction, of theories, 25, 72
Reverse reactions, 677, 680
concentration changes and, 692
proton transfer and, 724–25, 726
temperature and, 693
volume and, 694
Revision, of theories, 25, 72
Rounding, 814–15
Rubber, 445, 460
Rule of thumb, 741
Rusting. *See* Corrosion; Oxidation
Rutherford's atomic theory, 20–21, 78

S

Safety symbols, 809
Samples, 328, 596
SATP. *See* Standard ambient temperature and pressure (SATP)
Saturated fats and oils, 450
Saturated hydrocarbons, 366, 374
Saturated solutions, 221, 224–26
Schindler, David, 206
Science, 8
as compartmentalized vs. holistic, 564
reductionism of, 172
and technology, 8–9
technology and, 276, 478, 556, 558, 646, 690
Science, technology, and society (STS). *See* STS (science, technology, and society)
Scientific attitudes, 9, 795
Scientific knowledge, 9, 44. *See also* Empirical knowledge
changes in, 248
evolution from empirical to theoretical, 236
indigenous knowledge (IK) and, 163
technological problem solving and, 614–15
Scientific laws, 11, 154
Scientific notation, 812
Scientific perspectives, 45
Scientific problem solving, 614–15, 790–92
Scientific research, 8, 9, 794–95
Scientific research and development (R&D), 79, 359
Scurvy, 743, 744
Semiconductors, 127
Semi-metals, 14
toxicity of, 337
Series of elements, 16
Silicon, 588
Silver, 560, 650
Silver sulfide (tarnish), 120, 557
Simple decomposition reactions, 58
Single replacement reactions, 62, 561–62
SI (Système International d'Unités), 55, 149, 811–12
Skeleton equations, 579
Slaked lime, 511
Smelting, 560, 649
Soap, 103
Sodium hydrogen carbonate, 257, 268, 722, 723
Sodium hydroxide, 216, 234, 256, 330, 648, 715
Soil scientists, 301
Solar energy, 480, 483
Solids
motion of molecules in, 163
physical properties of, 119–30
solubility of, 221, 222
Solubility, 61, 221
charts, 61, 200, 201
generalizations about, 222–23
and oil and gas extraction, 362
of solids, 221
tables, 222–23
temperature and, 222
Solubility equilibrium, 677
Solutes, 61, 192
calculating quantities of, 206
conductivity for, 236
constant quantity of, 216–17
excess, 226
Solutions, 12, 13, 186, 192–93
calculating quantities of, 206
chemical reactions in, 61–63
concentration of, 203
energy changes and formation of, 199–100
in equilibrium, 224
and handling of chemicals, 220
pH of, 239, 240
preparation dilution, 216–18
preparation of, 803–804
reactions in, 281
saturated. *See* saturated solutions
Solution stoichiometry, 288, 300–302
Solvent extractions, 387
Solvents, 61, 192
water as, 190, 197
Sørensen, Søren, 239
Specific heat capacity, 485
Spectator ions, 283
Spectrophotometers, 315
Spectroscopy, 114, 315
Standard ambient temperature and pressure (SATP), 14–15, 149, 169, 295, 495, 510
Standard cell potential, 627
Standard cells, 627, 639
Standard enthalpy of formation, 510
Standardized solutions, 330–31, 597
Standard molar enthalpies of formation, 827
Standard molar enthalpies of reaction, 496
Standard reduction potentials, 627, 628–30
Standard solutions, 215–16, 330
Standard temperature and pressure (STP), 149, 169, 295
Starches, 456
Steacie, Edgar, 721
Stearic acid, 255
Steel, 120, 634, 636, 637
Stereochemical formulas, 88
Stereochemistry, 91
Steroids, 375
Stock solutions, 216
Stoichiometry, 287, 320–29
applications of, 292–93
of electric cells, 652–57
of redox reactions, 596–600, 676
STP. *See* Standard temperature and pressure (STP)
Strong acids, 200–201, 254–55, 718–20, 725, 726, 737
Strong bases, 256–55
Strontium chloride, 646
Strontium metal, 646
Structural analogs, 449
Structural formulas, 78, 85, 88, 89, 368, 372, 376
Structural isomers, 366–67
STS (science, technology, and society), 44–45, 79, 795, 806
Styrene, 447
Substitution reactions, 421–22
Sugar, 106
Sulfur
compounds, 394
in gasoline, 393–94
impurities in fuels, 332
Sulfur dioxide, 145, 252, 332, 363, 393
Sulfur dioxide gas, 171
Sulfuric acid, 145, 200–201, 255
Sulfur trioxide, 145
Superacids, 724
Sustainable development, 357
Syntheses, 107, 173

T

Tables, 815
Tables of evidence, 10
Tarnish. *See* Silver sulfide (tarnish)
Tartaric acid, 437
Taube, Henry, 561
Taylor, Richard, 23

Technological applications, 45
Technological perspectives, 45
Technological problem solving, 236, 796
  quality control tests, 293
  scientific knowledge and, 614–15
  trial-and-error approach to, 219, 276, 615
Technology/technologies. *See also* Chemical technologies
  of Aboriginal peoples, 276, 449, 614, 615, 621
  alternative energy, 507–508
  context of, 276
  contexts of applications, 236
  energy and, 474
  and environment, 277
  goal of, 276, 286
  implementation of, 277
  and nonrenewable resources, 277
  obsolescence of, 277
  pollution-reducing, 252
  science and, 8–9, 276, 478, 556, 558, 646, 690
  and social change, 277
  as solving practical problems, 276, 286
  sustainability of, 277
  testing in, 631
  time and, 277
  transfer, 621
Teflon (polytetrafluoroethylene), 447–48
Temperature
  changes, 498, 502
  equilibrium and, 719
  and equilibrium constant, 685
  and forward/reverse reactions, 693
  Le Châtelier's principle and, 693
  measurement technologies, 155–56
  reaction equations and, 279
  and solubility, 222
  volume and, 152–56
Testing, 248, 290, 291, 578, 597, 631, 710
Tetrahedral bonds, 92, 93, 94
Theoretical definitions, 18, 724
Theoretical descriptions, 18
Theoretical hypotheses, 18
Theoretical knowledge, 10
Theories, 9, 18, 98, 710
  empirical knowledge vs., 524–26
  evaluation of, 24–25
  evolution of, 733–35
  falsification of, 25
  and prediction of results in new situations, 42, 251
  proving of, 25
  replacement of, 25, 72
  restriction of, 25, 72
  revision of, 25, 72
  use of, 250
  validity of, 42
  verification of, 25
Theory of ionic dissociation, 526
Thermal cracking, 389
Thermal energy, 485
Thermal stability, 510
Thermochemistry, 474, 485
Thermometers, 155
Thomson, Sir William. *See* Kelvin, Lord
Thomson's atomic model, 19, 20
Thymol blue indicator, 336
Tires, 146, 159, 166, 185
Titrants, 328, 596, 751
Titrant solutions, standardizing, 330–31
Titration, 312, 328–39, 596, 751, 804
  acid–base indicators for, 336
  of acid–base reactions, 333
  pH changes during, 333
  pH curves, 334–35
Titration analysis, 314, 328–29
Toluene, 382
Torricelli, Evangelista, 149
Toxicologists, 204
Traditional ecological knowledge, 574. *See also* Indigenous knowledge (IK)
Transfats, 450, 451
Transistors, 127
Transition elements, 16
Transuranic elements, 16
Trial-and-error approach, 219, 228, 276, 318, 536, 615
Tri-esters, 449
Trigonal planar, 92
Triple bonds, 85

U

Ultraviolet (UV) radiation, 530
Uncertainty in science, 9, 44, 292, 795, 814
Universal gas constant, 173
Unsaturated fats, 450
Unsaturated hydrocarbons, 374
Urea, 349, 696–97
Urry, Lewis, 619

V

Valence electrons, 78, 81, 83, 85, 87, 124
Valence orbitals, 80
Valve trays, 386
Vanadium, 128, 586, 608
Van der Waals forces, 105–106, 173
Van't Hoff, Jacobus, 78, 82
Vaporization, 106, 109
Vapour deposition, 650
Vinyl benzene, 447
Vinyl chloride, 447
Viscosity, 386
Vitamin C, 438, 743, 744
Vitamins, water-soluble, 438
Volatile organic compounds (VOCs), 118, 383, 384, 426
Volatility, 113
Volta, Alessandro, 612, 622
Voltage, 613, 628
Voltaic cells, 622–26, 627, 639, 641
Voltaic pile, 612
Voltammetry, 337
Voltmeter, 613, 627, 628, 632
Volts, 613
Volume
  absolute temperature and, 154
  calculation of, 209
  and gas volume changes, 694
  Le Châtelier's principle and, 694
  pressure and, 150–52, 694
  temperature and, 152–56
Volumetric glassware, 215
VSEPR theory, 91–94
  multiple bonds in, 96–100

W

Waage, Peter, 684
Waste disposal, 810
Water. *See also* Aqueous solutions; Hydrologists
  acid–base reaction with, 249–50
  for fossil fuel extraction and refining, 360
  generalizations about solubility in, 222–23
  geometry of, 94
  hard, 63, 216
  ionization constant for. *See* Ionization constant for water, K_w
  oil recovery and, 388
  purity, 190, 238, 714
  repellents, 105
  soft, 63
  solubility in, 201
  as solvent, 197
  as universal solvent, 190
  as vapour, 53
Water and waste treatment plant operators, 200
Watson, James D., 113
Watts, 614
Weak acids, 201, 254–55, 718–20, 726, 737, 740–41
Weak bases, 256–57, 744, 745–46
Weather forecasts, 167
Weight, 149
Wöhler, Friedrich, 696
Wood alcohol. *See* Methanol
Wood pulp, bleaching of, 594
Workplace Hazardous Material Information System (WHMIS), 809
Written response questions, 824–25

X

Xu, Yunjie, 115

Y

Yener, Aslihan, 567

Z

Zero energy, 510